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A PRELIMINARY EXAMINATION OF AREAL CHARACTERISTICS OF PRECIPITATION IN NEW MEXICO

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A PRELIMINARY EXAMINATION OF AREAL CHARACTERISTICS OF PRECIPITATION IN NEW MEXICO

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INTRODUCTION

Probability concepts which have been introduced into routine forecast issuances over the past few years have yielded many side benefits in addition to the numerical specification available to the lay user. Foremost among these is obviously a vastly improved, sharper, and more realistic verification system which has enabled the forecaster to more accurately assess his abilities and to consciously work toward correcting systematic errors. Skill scores, reliability graphs, "I-scores", etc., have been discussed widely and have served as useful aids to the conscientious forecaster.

But implicit in any point probability forecast of precipitation is the relation $P = (P_r)(A)$ where "P" is the point probability, "P_r" is the basic probability of the event occurring, and "A" represents the fraction of the target area covered by the precipitation. "P" is the subjective estimate announced in the forecast. In deciding on a value for "P", the forecaster must have, consciously or otherwise,considered the basic probability of the event occurring <u>and</u> the expected areal coverage, "A". For large sections of the country and for many meteorological situations (especially cold-season types), "A" is tacitly assumed to be unity or very nearly so and is thus a negligible factor. The current study was undertaken to determine whether this assumption ("A" near 1.0) was valid in New Mexico. The conclusions presented below, if valid, can of course, be extended with appropriate modifications to areas of comparable climatological regimes. A similar contemporary work by Curran and Hughes studied the effect of areal coverage on precipitation probability forecasting for an 11,000 square mile area in Kentucky. (WBTM CR-24, Sept. 1968)

CLIMATOLOGICAL DIVISION OF STATE

The basic object of the investigation was to gain some idea of typical, average, most likely, least frequent, etc., areal coverages of precipitation situations. (We follow the usual definition: .01 inch or more.) Since New Mexico is characterized by a considerable range of elevations (near three thousand to near thirteen thousand feet), terrain types varying from extensive and essentially flat plains to rugged mountain massifs, and from broad, low river basins with desert type vegetation to high, arid valleys; and since several basic source regions of moisture may be significant in different seasons and situations, it was natural to attempt some division of the state for an attempt at meteorological homogeneity. This division is presented

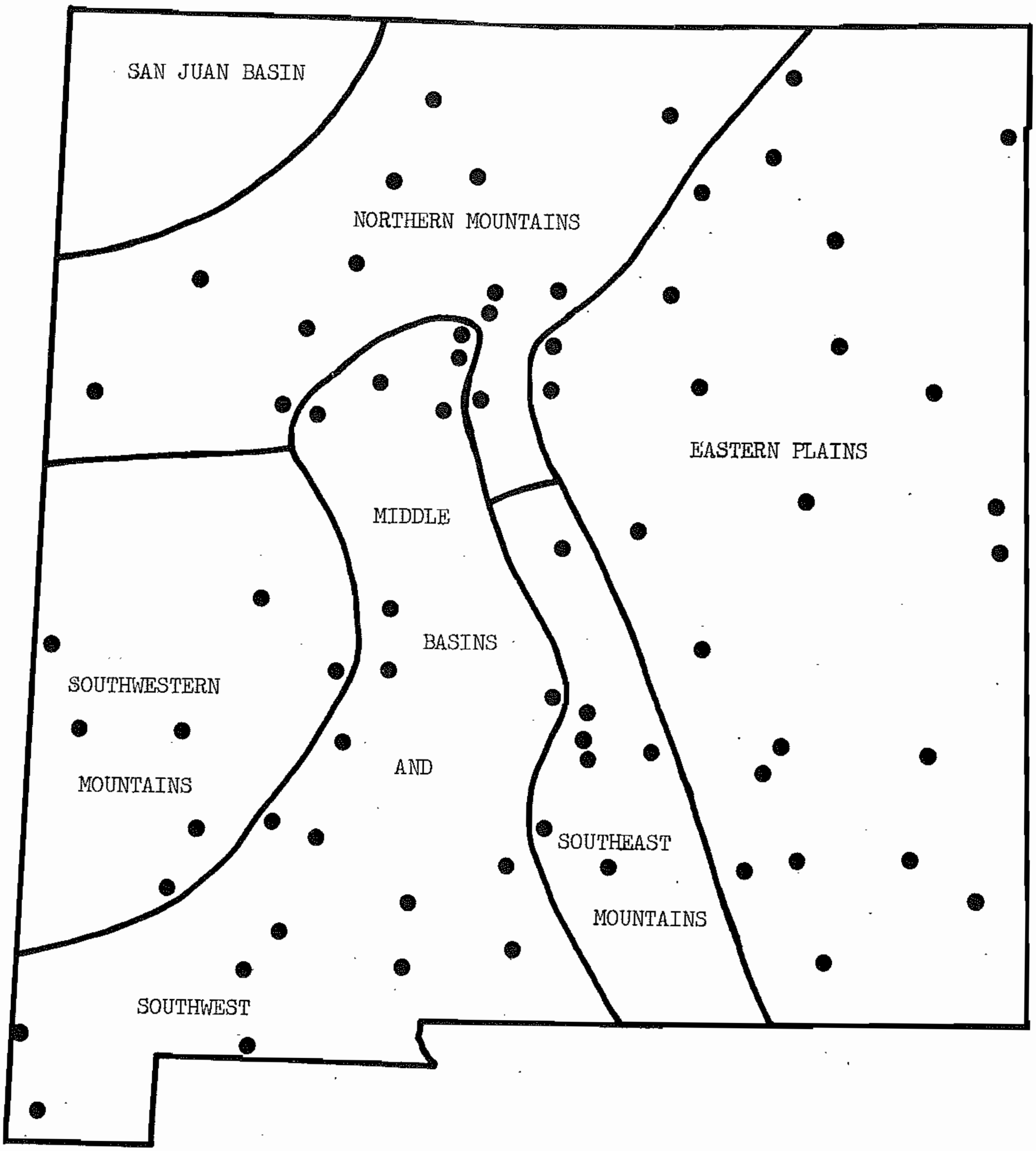

SAN JUAN BASIN
NORTHERN MOUNTAINS
EASTERN PLAINS
MIDDLE
BASINS
AND
SOUTHWESTERN
MOUNTAINS
SOUTHEAST
MOUNTAINS
SOUTHWEST

Figure 1

in Figure 1 without spirited justification. Experienced individual forecasters and climatologists might, with ample reason, argue for shifting boundaries slightly to include or exclude given stations from labeled areas. But in the main and especially as far as this particular investigation is concerned, we feel that the boundaries and definitions are adequate.

DATA COVERAGE

Data source was the EDS publication, "Hourly Precipitation Data, Daily Totals". Location of stations is indicated in Figure 1. In normal fashion, records were occasionally missing for various stations for various periods. These missing data were taken into consideration in the evaluations. No summary was attempted nor conclusions drawn for the area labeled "San Juan Basin". It was excluded because only one consistently reporting gauge is located in this area, too small a sample for reliable conclusions, and the climatological regime of the basin is almost certainly different from that of adjacent divisions.

For the remaining part of the state, this leaves an average of 70 recording rain gauges for approximately 122,000 square miles, an average density of one gauge per 1700 square miles. Broken down by divisions we obtain the following approximate comparative densities:

DIVISION	AREA	GAUGES	DENSITY (Sq. Mi. Per Gauge)
Eastern Plains	39,000	23	1700
Northern Mountains	28,500	12	2400
Southwest Mountains	14,500	7	2000
Southeast Mountains	9,500	7	1400
Middle Valleys and Basins and Southwest	25,000	20	1300

Densities of coverage are, thus, very roughly comparable though the net is admittedly thin. However, it is the best available for automatic, 24-hour coverage. Moreover, a prior unpublished study by the author established, for the same overall area, the essential validity of an even smaller sample when compared to complete climatological reports. Hence, we consider conclusions drawn from the net statistically defensible.

Analysis. To agree with standard forecast verification periods, the 24-hour day was divided into two periods, 12Z-00Z and 00Z-12Z. For each period a tabulation was made of each reported precipitation event and, for these periods in which precipitation was recorded at any station in the division, the percentage of stations reporting precipitation was computed. This figure is assumed to, within reason, represent the areal coverage. Obviously, in almost any particular instance the assumption may well be erroneous; the rains may happen to unjustly favor the stations in the net; or they may inexplicably skip observing points with no rhyme nor reason; every experienced forecaster

RELATIVE FREQUENCY OF OCCURRENCE PER CLASS

4.

DIVISION	SEASON	TIME OF DAY	0-9.5	10-19.5	20-29.5	30-39.5	40-49.5	50-59.5	60-69.5	70-79.5	80-89.5	90-100	Avg Areal Coverage for pcpn days	% Days with Pcpn
NORTHERN MOUNTAINS	ANN	05-17M	.33	.22	.14	.09	.05	.05	.04	.03	.03	.02	.27	.36
		17-05M	.27	.23	.13	.11	.05	.09	.05	.02	.03	.02	.29	.33
	WET	05-17M	.35	.22	.16	.12	.07	.05	.01	.01	.01	.01	.23	.68
		17-05M	.28	.24	.15	.11	.05	.07	.06	.01	.03	.01	.28	.59
	DRY	05-17M	.39	.21	.11	.03	.03	.04	.09	.05	.06	0	.33	.19
		17-05M	.26	.22	.11	.12	.06	.11	.03	.02	.03	.03	.30	.20
EASTERN PLAINS	ANN	05-17M	.43	.24	.16	.07	.04	.02	.02	0	.01	0	.18	.39
		17-05M	.38	.18	.18	.10	.06	.03	.03	.02	.02	0	.22	.36
	WET	05-17M	.35	.31	.19	.07	.05	.01	.01	0	.01	.01	.18	.72
		17-05M	.35	.18	.20	.11	.06	.03	.04	.02	.01	0	.23	.72
	DRY	05-17M	.54	.14	.12	.07	.02	.05	.04	.01	.02	0	.18	.22
		17-05M	.42	.20	.14	.08	.04	.02	.02	.02	.05	0	.22	.19
SOUTHWEST MOUNTAINS	ANN	05-17M	0	.31	.15	.15	.11	.11	.05	.04	.04	.04	.38	.29
		17-05M	0	.28	.16	.12	.13	.12	.06	.01	.04	.08	.40	.24
	WET	05-17M	0	.27	.19	.18	.11	.13	.06	.01	.02	.02	.36	.59
		17-05M	0	.25	.18	.16	.15	.10	.07	0	.04	.05	.38	.45
	DRY	05-17M	0	.41	.06	.09	.09	.05	.05	.09	.08	.09	.42	.14
		17-05M	0	.34	.11	.05	.10	.16	.03	.03	.05	.13	.44	.13
SOUTHEAST MOUNTAINS	ANN	05-17M	0	.27	.13	.14	.08	.18	.08	.02	.06	.04	.41	.28
		17-05M	0	.34	.13	.13	.06	.12	.05	.02	.12	.03	.40	.24
	WET	05-17M	0	.25	.14	.17	.09	.17	.10	.03	.03	.02	.39	.59
		17-05M	0	.33	.18	.13	.04	.13	.05	.01	.10	.02	.38	.46
	DRY	05-17M	0	.32	.10	.06	.06	.18	.05	.03	.11	.10	.48	.13
		17-05M	0	.35	.05	.14	.08	.11	.03	.03	.15	.06	.44	.13
MIDDLE VALLEYS & BASINS & SW	ANN	05-17M	.29	.31	.19	.09	.04	.04	.02	0	.01	.02	.21	.33
		17-05M	.26	.25	.16	.14	.07	.05	.02	.02	.01	.03	.25	.31
	WET	05-17M	.25	.32	.22	.09	.04	.04	.02	.01	.01	0	.20	.62
		17-05M	.22	.25	.20	.15	.08	.06	.01	.01	.01	.02	.25	.60
	DRY	05-17M	.35	.27	.14	.09	.03	.05	.01	0	.01	.05	.22	.18
		17-05M	.32	.25	.09	.12	.05	.03	.04	.03	.01	.04	.25	.16

TABLE I

Since the time of primitive peoples it has been well recognized that precipitation has a strong seasonal character in the Southwest, both in regard to frequency and to amount. The warm season maximum is clearly defined in records ranging from the mute but graphic evidence of tree rings to the more refined forms of cellulose residing in the vaults of Asheville. Hence, it was considered advisable to look at seasonal variations of coverage. The wet season centers on the midsummer months of July and August but frequently laps over into parts of June and September. For this examination we arbitrarily defined the wet season as June, July, August, and September with remaining eight months labeled dry (better, not wet). Separations of the data were then made in the manner previously described according to these definitions. These results are also contained in Table I with appropriate labeling.

Close perusal of Table I will disclose surprisingly small seasonal difference in relative frequencies per geographical division, in fact, so little that we attach only minor significance to it. The same pattern is consistent: relative frequencies of .5 or more in the lowest two coverage categories and very low relative frequencies in the high-coverage classes. So apparently the synoptic-scale disturbances of the not-wet seasons seldom yield appreciably greater areal coverages than the essentially meso-scale, mainly air-mass types, (or are they?) of the summer season. In verification studies we have habitually noted higher ranges of reliability for winter precipitation events, but this may be attributable to the ability to more precisely time precipitation occurrence and to relate them better to the sharper circulation patterns characteristic of the vigorous westerly circulations of the cold season.

Another generally assumed but unproved hypothesis concerns frequency of precipitation as related to geographical features. It is generally assumed that rains and snows occur more frequently over the higher terrain, "Showers and snow flurries mountains of north," etc., and less frequently over plains and valley areas. The final column of Table I contains figures to provide some test for the validity of this hypothesis. For each time separation (wet season, dry season, time of day, etc.) these figures represent the fraction of days with rain reported in the geographical division, i.e., the percentage of days with at least one report of measurable rain.

In consideration of these time-frequencies, note first the diurnal characteristics. For the area in general there appears to be very little difference in frequencies between day and night with an overall very slightly higher frequency for daytime hours - probably too slight to be of practical significance. However, for the summer season, the mountain divisions do appear to show a slight preference for daytime rain activity. This preference is not surprising; the small degree of preference is. For divisions which are predominantly valleys or plains, there appears to be no significant difference in frequency between day and night precipitation; and that for mountain divisions is evident only for the warm season.

has often ruefully noted such occurrences. But we feel that, over a relatively large number of occasions, the unbalances will iron out and the percentage figure will reasonably well represent areal coverage. With such considerations, 24 consecutive months of data were examined, November 1965 through October 1967, thus embracing all seasons.

Then, for each geographical division and for each period the percentage classes were grouped into deciles. From this grouping relative frequencies were computed for classes. These are presented numerically in Table I and graphically in Figures 2-6. It should be noted that these histograms do not represent the percentage of times precipitation coverage was as shown relative to the total number of days. Rather, the frequencies are with respect only to the total number of days with precipitation in that particular geographical division.

Findings. Some comment is offered in reference to Figure 2 by way of general explanation. Note that on approximately one-third of the days (or nights) with rain, the areal coverage was 10 percent or less. Moreover, if we consider cumulative frequencies, more than half the days with precipitation had areal coverages of 20 percent or less. This is a most imposing figure when the forecaster is striving to offer his clientele a meaningful and useful probability statement. He can reliably specify a probability higher than 20 percent less than half the time! Furthermore, look at the top end of the scale. Total relative frequencies of 50 percent or higher are about .2. Hence, he can make a categorical forecast of precipitation for only about 20 percent of the days with precipitation (which are about 35 percent of the days in the year). It is seen then that for this area a categorical rain forecast should be essayed only very sparingly, and a high-probability forecast (.8 or more) only rarely. Indeed, areal coverages of 80 percent or more were observed on only 5 percent of the precipitation days.

GEOGRAPHICAL AND SEASONAL CHARACTERISTICS

Furthermore, examination of Table I and the remaining histograms (Figures 3-6) shows that this particular geographical division does not constitute an exception. All divisions display the same general characteristics as far as high frequencies in the low classes (sparse coverage) and low frequencies in the high classes are concerned. This is most evident in the "Eastern Plains" Division and might legitimately be objected to due to size of the division. However, we feel that if this relatively large division was, for example, split in half, the large low-class frequencies would be decreased by less than .1, not enough to negate the primary conclusion. Note that the limited number of stations (five to seven) for "Southwestern Mountains" and "Southeastern Mountains" obviated classes below 14 percent. But the trend and conclusions remain essentially unchanged when the data is reasonably smoothed...

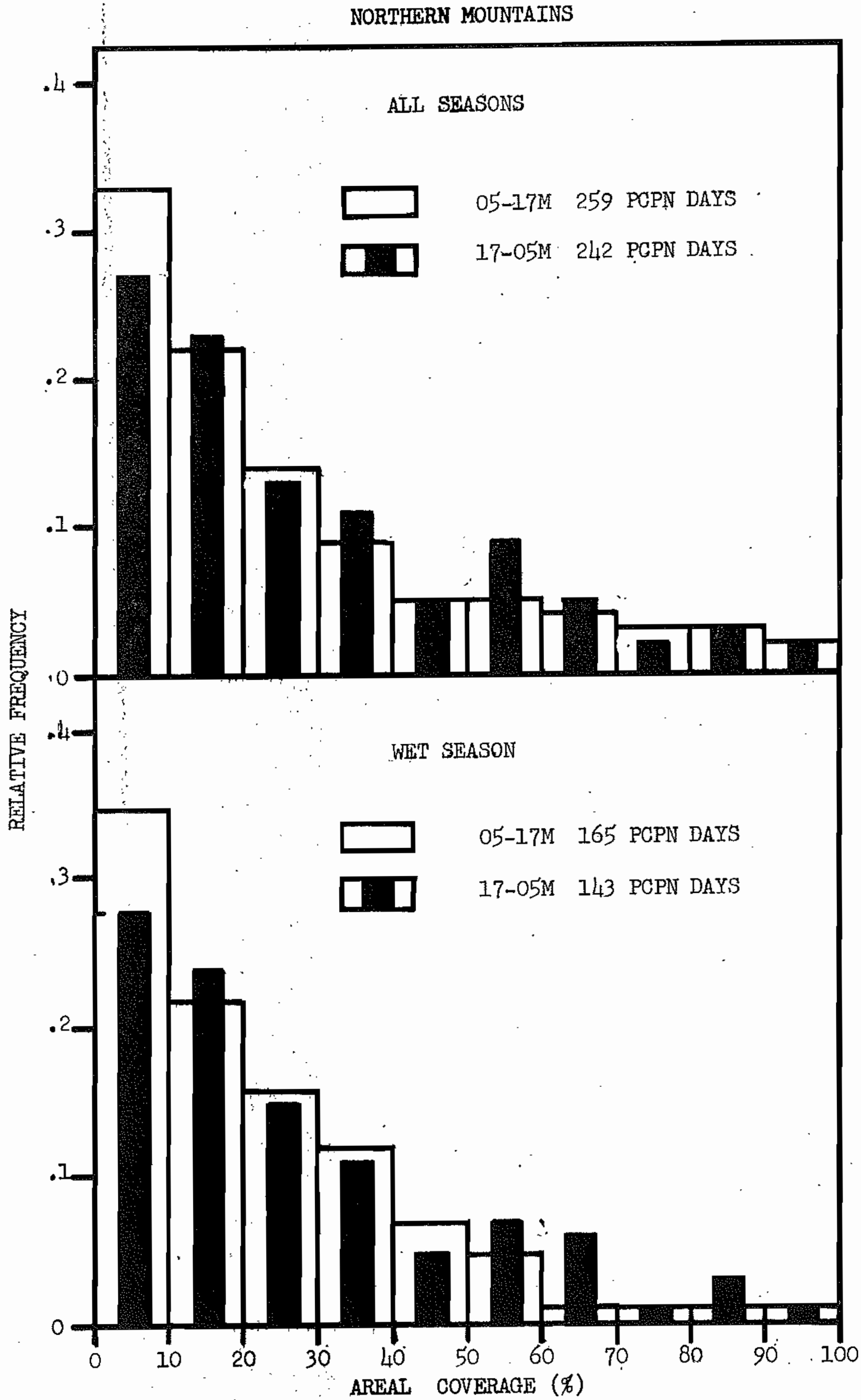

NORTHERN MOUNTAINS
ALL SEASONS
05-17M 259 PCPN DAYS
17-05M 242 PCPN DAYS
WET SEASON
05-17M 165 PCPN DAYS
17-05M 143 PCPN DAYS
RELATIVE FREQUENCY
.4
.3
.2
.1
0
0 10 20 30 40 50 60 70 80 90 100
AREAL COVERAGE (%)

Figure 2

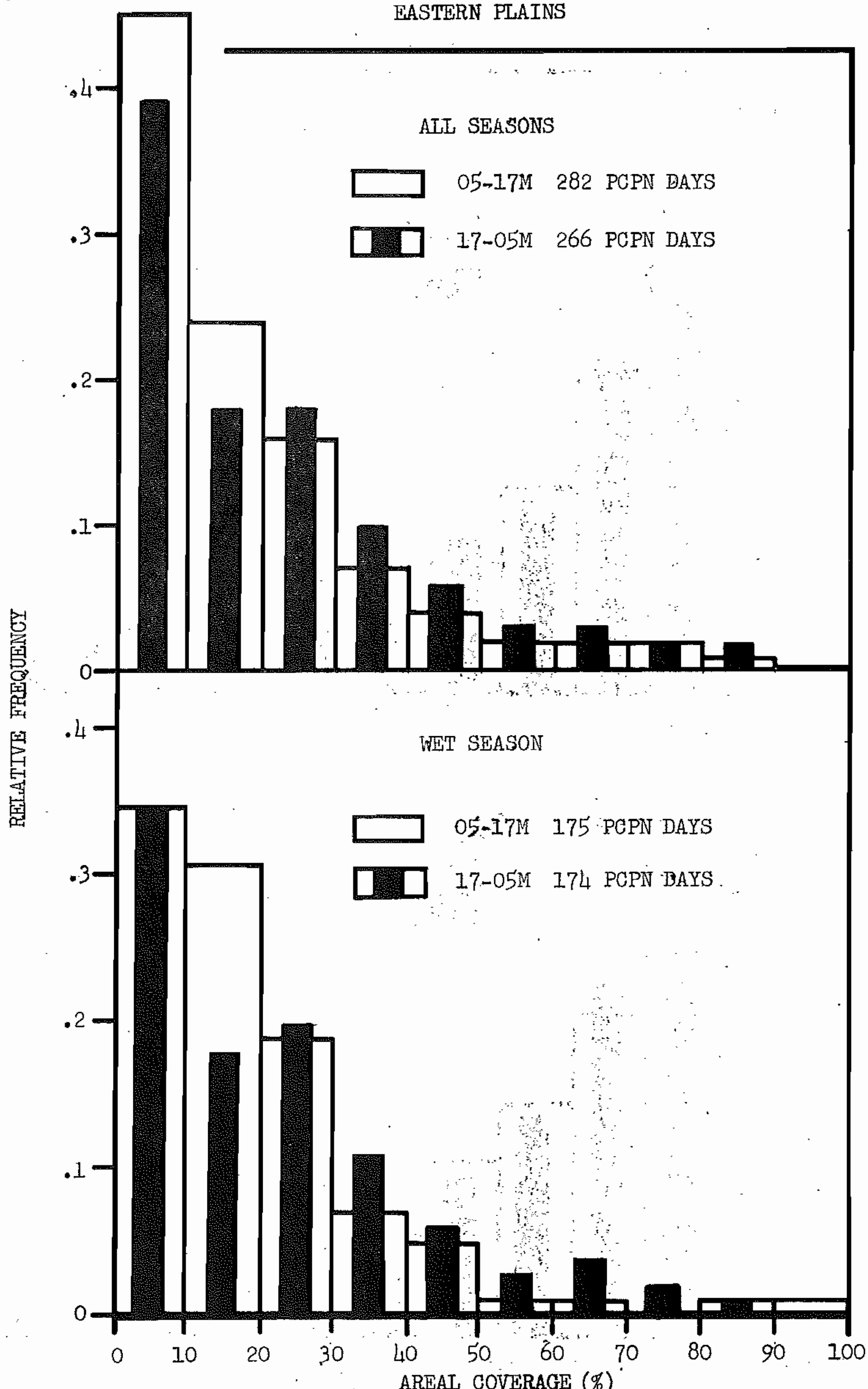
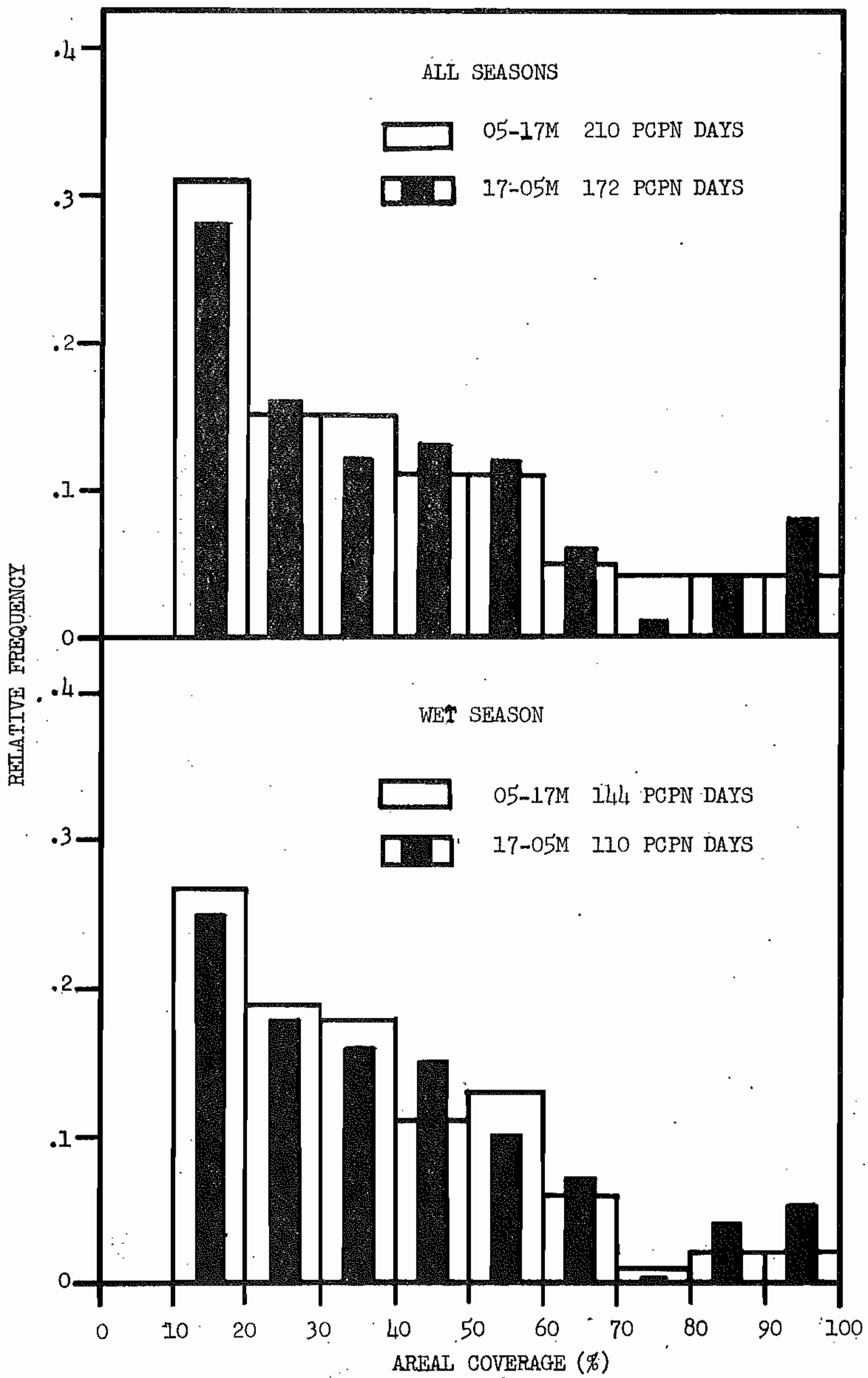

EASTERN PLAINS
ALL SEASONS
05-17M 282 PCPN DAYS
17-05M 266 PCPN DAYS
WET SEASON
05-17M 175 PCPN DAYS
17-05M 174 PCPN DAYS
RELATIVE FREQUENCY
.4
.3
.2
.1
0
0
10
20
30
40
50
60
70
80
90
100
AREAL COVERAGE (%)

Figure 3



ALL SEASONS
05-17M 210 PCPN DAYS
17-05M 172 PCPN DAYS
WET SEASON
05-17M 144 PCPN DAYS
17-05M 110 PCPN DAYS
RELATIVE FREQUENCY
0
.1
.2
.3
.4
0 10 20 30 40 50 60 70 80 90 100
AREAL COVERAGE (%)

FIGURE 4

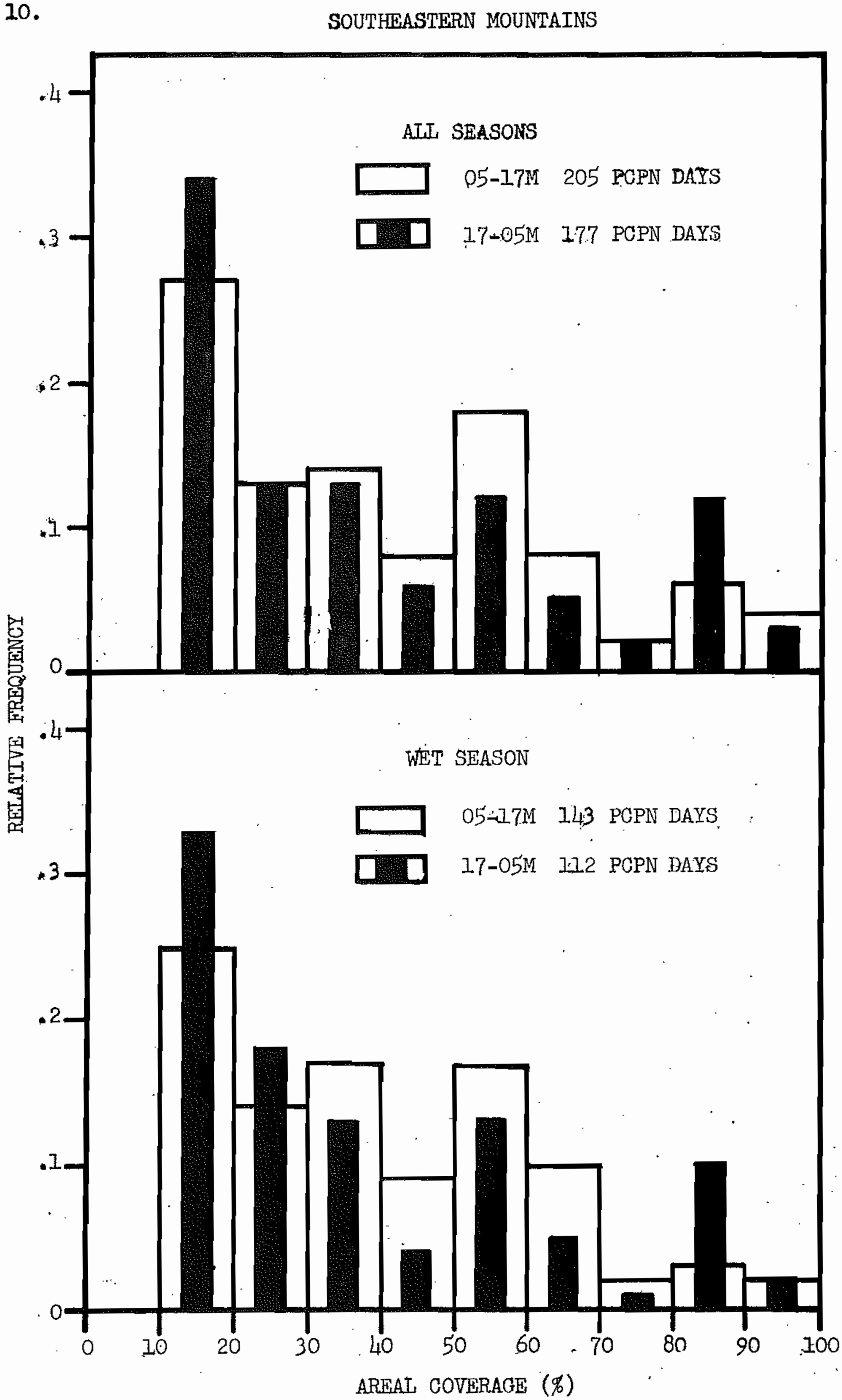

SOUTHEASTERN MOUNTAINS
ALL SEASONS
05-17M 205 PCPN DAYS
17-05M 177 PCPN DAYS
WET SEASON
05-17M 143 PCPN DAYS
17-05M 112 PCPN DAYS
RELATIVE FREQUENCY
.4
.3
.2
.1
0
0
10
20
30
40
50
60
70
80
90
100
AREAL COVERAGE (%)

Figure 5

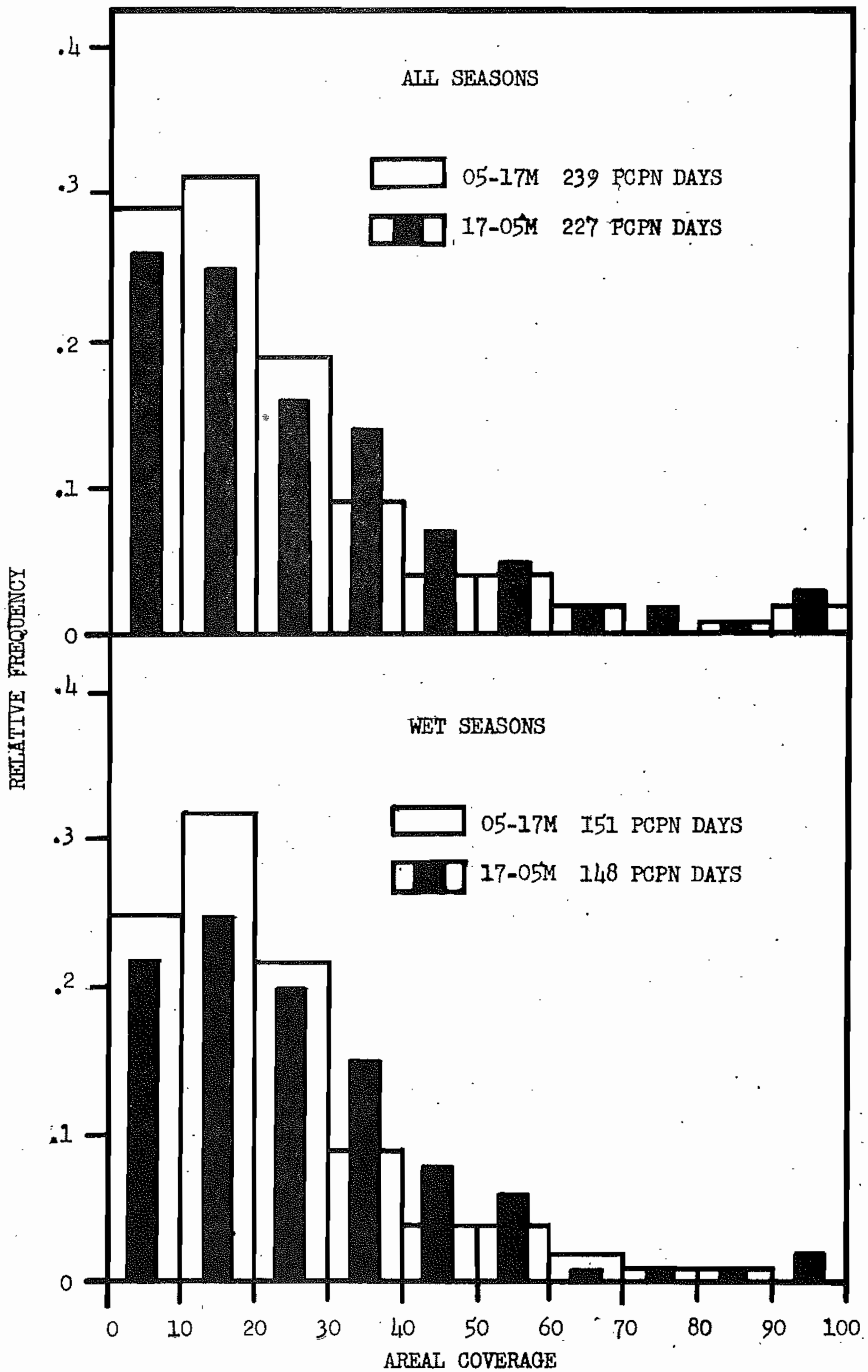

ALL SEASONS
05-17M 239 PCPN DAYS
17-05M 227 PCPN DAYS
WET SEASONS
05-17M 151 PCPN DAYS
17-05M 148 PCPN DAYS
RELATIVE FREQUENCY
.4
.3
.2
.1
0
0
10
20
30
40
50
60
70
80
90
100
AREAL COVERAGE

Figure 6

Comparative frequencies between divisions certainly show little to support the hypothesis of more frequent rains and snows in mountain sections. Whether one considers all-season data, cold season or warm season, day or night, there is very little difference demonstrated between geographic divisions by these statistics. Indeed, what little difference exists tends to favor plain and valley divisions over those which are essentially mountainous. However, note that the gradient of frequencies is in the same direction as the gradient of areas and may well be totally related to the number of reporting stations. We prefer to avoid a definite conclusion but the evident inability to demonstrate a positive conclusion strikes severely at the hypothesis. A more searching and detailed test of the validity of the hypothesis seems in order.

POINT PROBABILITY SPECIFICATION

The remaining statistic in Table I (next to final column) is the simple arithmetic mean of areal coverage for the days with precipitation. This figure clearly varies inversely with size of the area, a not illogical tendency.

In consideration of these two final columns, the first could be read as the climatological probability of rain somewhere in the division and the second as the areal coverage when rain occurs. The product then should approximate the climatological point probability. The products were computed and compared to the isopleths of "Climatological Probability of Precipitation" prepared and distributed by TDL. February was chosen to represent the not wet season and July the wet season. Magnitudes and trends (dry to wet season) agreed very well with an average difference of four percent, the TDL point figures being slightly higher.

It is seen then that, at least for this type of climate, the great mass of point probability specifications must be for values of .3 or lower. For all divisions and all seasons considered together, the cumulative relative frequency curve, Figure 7, reaches .5, well below the 30 percent coverage mark, i.e., more than half the time when measurable precipitation falls in a division, the areal coverage is less than 30 percent. Moreover, we see from Figure 7 that areal coverages of 50 percent or higher are attained on less than .2 of the rain occasions; and coverages of 70 percent or higher occur in less than .1 of the rain situations. Rain is, indeed, a chancy commodity in the Southwest; and the appearance of a shower in the near distance is clearly more apt to tempt the gardener than it is to reward him.

Forecasting Applications. The implications for probability forecasting are evident. We have noted a growing acceptance from the public of probability specifications;and we are not infrequently asked for a figure when it is for some reason omitted from the forecast. Yet, as demonstrated above, the forecaster can with reliability extend his point probability specifications above the 30 percent category in less than

OVERALL AVERAGE

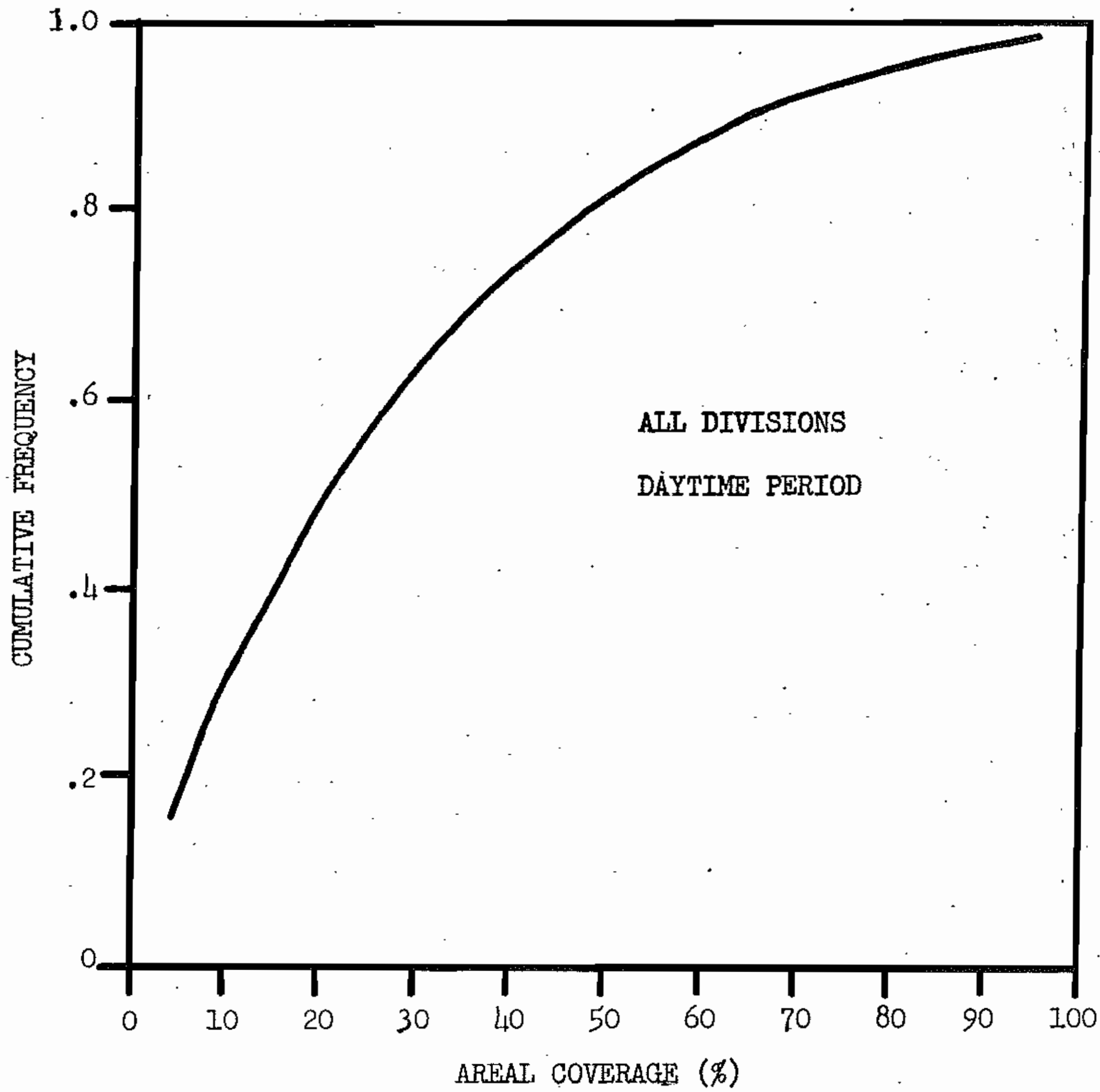


Figure 7

half the rain situations and can with reliability make a categorical (50 percent greater probability) rain forecast in only about one-fifth of the rain-threat cases. Ordinarily probabilities are not publicly announced or precipitation threats mentioned in the forecast when the probability is less than 10 percent. Hence, mention of precipitation in the forecast is most likely to be accompanied by a specification figure of 10, 20, or 30 percent.

Incidentally, a significant contributing factor to the experience-forced use of relatively low figures is signaled by the often-used phrase "Afternoon or Evening Showers". The forecaster is usually hard put to decide which time is more favorable; we suspect a time-of-day frequency statistic would display the favorite precipitation time in the Southwest centers around 00Z. Hence, if a forecaster is 70 percent sure rain will develop in measurable amounts and knows the areal coverage will be .6, he is probably not more than half positive whether it will fall before or after 00Z. So he assumes the conditions are independent, multiplies .7 by .6 by .5 and can legitimately announce a likelihood of only 20 percent for each period! More typically, he is apt to arbitrarily decide in favor of one period over the other and either announce "20 percent this afternoon, 30 percent tonight" or vice versa. At any rate, the time uncertainty must materially lower the published and announced figure. It is suggested that time periods might usefully be less sharply defined. Probably only two specifications per forecast would be equally useful and less confusing, e.g. "50 percent Today, 40 percent Tomorrow", "40 percent Tonight, Increasing to 60 percent Tomorrow Afternoon", etc. Prevailing definitions could still be retained and recorded for verification purposes, an important and most useful and appreciated feature of probability forecasting.

Or, if this "afternoon-or-evening" dilemma is not characteristic only of the Southwest but exists generally, consideration might be given to redefining forecast periods. One might, for instance, use the 12-hour intervals 18Z-06Z (This afternoon and evening), and 06Z-18Z (Late tonight and tomorrow morning). These divisions of the day seem more likely to correspond to times of maximum and minimum rain frequency.

LIST OF SOUTHERN REGION TECHNICAL MEMORANDA

No. 1 Selection of Map Base for Small Scale Analysis and Prediction. Woodrow W. Dickey - May 19, 1965

No. 2 The Relationship of K-Values to Areal Coverage of Showers in the Mid-South. Jack Hollis and Kenneth E. Bryan - August 1965

No. 3 Some Notes on Waterspouts around the Lower Keys. R. Larry Mayne - August 1965

No. 4 Tornadoes Associated with Cyclones of Tropical Origin - Practical Features. E. L. Hill, William Malkin and W. A. Schulz, Jr. - September 1965

No. 5 Radar Echoes Associated with Waterspout Activity. Dorus D. Alderman - October 1965

No. 6 Probability Forecasting. Woodrow W. Dickey - October 1965

No. 7 Short Period Forecasting. Jeter A. Pruett - November 1965

No. 8 Southwest Texas Soaring Weather. David H. Owens - November 1965

No. 9 A Survey of Research in Agricultural Meteorology. Donald A. Downey - November 1965

No. 10 A Quick Look at the Results of One Month's Precipitation Probability Forecasting. George T. Gregg - January 1966

No. 11 Severe Storm Warning Systems in the Southern Region. Staff Members of Operations Division, Southern Region - February 1966

No. 12 The Lubbock Snowstorm of February 20, 1961. Billie J. Cook - April 1966

No. 13 Summary of Probability of Precipitation Forecasts in the Southern Region for the Period January through March 1966. Woodrow W. Dickey - May 1966

No. 14 Air Pollution Meteorology and Transport of Pollutants. Jose A. Colon - June 1966

No. 15 On the Mechanisms for the Production of Rainfall in Puerto Rico Jose A. Colon - June 1966

No. 16 Teletype Techniques and Presentation Procedures for Public Weather Circuits. Jack Riley - June 1966

No. 17 Summary of the Pre-FP - Post-FP Forecast Verification Experiment. Woodrow W. Dickey - June 1966

No. 18 Fire Weather in the Southeast. Richard A. Mitchem - July 1966

No. 19 Severe Storm Warning Networks in Oklahoma. Gerald J. Carter and W. O. Garrison - July 1966 (continued) LIST OF SOUTHERN REGION TECHNICAL MEMORANDA

No. 20 Climatological Aids to Short Range Forecasting. Jerome H. Codington - August 1966

No. 21 A review of the Methods Developed for Forecasting Stratus in South Central Texas. Richard S. Schrag - August 1966

No. 22 Agricultural Forecasting at Tallahassee, Florida. J. S. Smith - August 1966

No. 23 The Use of Radar in Flash Flood Forecasting. Jack L. Teague - August 1966

No. 24 Short Range Forecasting Procedures at Savannah. David P. Barnes - August 1966

No. 25 On the Use of Digitized Radar Data for the Florida Peninsula. Neil L. Frank Paul L. Moore and George E. Fisher - Sept. 1966

No. 26 Relative Humidity in Georgia. Horace S. Carter - Sept. 1966

No. 27 Study on Duration of measurable Precipitation at Birmingham. Hugh B. Riley - September 1966

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No. 29 On the Correlation of Radar Echoes over Florida with Various Meteorological Parameters. Neil L. Frank and Daniel L. Smith - October 1966

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No. 31 A simple Inexpensive Degree-Hour Counter. D. R. Davis and Jerrell E. Hughes - March 1967

No. 32 An Objective Technique for Forecasting the Possibility of an Afternoon Summer Shower at Savannah, Georgia. David P. Barnes, Jr. and Samuel C. Davis - March 1967

No. 33 An Empirical Method for Forecasting Radiation Temperatures in the Lower Rio Grande Valley of Texas. Leroy B. Hagood - March 1967

No. 34 Study on Duration of Measurable Precipitation at Lubbock, Texas. G. Alan Johnson and Thomas P. Clarke - April 1967

No. 35 Remoting Radar Scope Weather and Associated Data via the Slo-Scan Method. Davis Benton - May 1967

No. 36 Short Range Forecasting of Dryoff Time From Dew Block Dew Intensity. Dorus D. Alderman and Kenneth E. Bryan - October 1967

No. 37 The Relationship of K-Values to Probability of Showers in the Mid-South. Kenneth E. Bryan - October 1967

No. 38 Florida Hurricanes. Gordon E. Dunn and Staff NHC, Miami November 1967

No. 39 The Relationship of Precipitation and Cloudiness to some Predictors from the NMC Six-Layer Model. Staff SSD, WBSRH - October 1968